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COMMERCIAL FERTILIZERS:

COMPOSITION AND USE.

BY

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COMMERCIAL FERTILIZERS.

There is, perhaps, no question of greater importance to the practical farmer than that of soil fertility. To produce profitable crops and at the same time to maintain and even to increase the productive capacity of the soil may rightly be termed "good farming." Many farmers are able to do this, and the knowledge of *how* to do it has been largely acquired through years of experience, during which the character of the soil, its adaptability for crops, and the methods of its management and manuring have been made the subjects of careful study, without, however, any definite and accurate knowledge concerning manures and their functions in relation to soils and crops. Experience is an excellent teacher; still, a definite knowledge of first principles may be substituted for years of experience in the successful use of manures.

THE NEED OF COMMERCIAL FERTILIZERS.

The fertility of the soil would remain practically unchanged if all the ingredients removed in the various farm products were restored to the land. This is to a large extent accomplished by feeding the crops grown on the farm to animals, carefully saving the manure and returning it to the soil, and if it is practicable to pursue a system of stock feeding in which those products of the farm which are comparatively poor in fertilizing constituents are exchanged in the market for feeding stuffs of high fertilizing value the loss of soil fertility may be reduced to a minimum or there may be an actual gain in fertility.

The following table, showing the amounts of fertilizing constituents in 1 ton of different agricultural products, indicates directions in which such an exchange may be effected with advantage:

Manurial constituents contained in 1 ton of various farm products.

	Nitrogen.	Phosphoric acid.	Potash.
	Pounds.	*Pounds.*	*Pounds.*
Meadow hay	20.42	8.2	26.4
Clover hay	40.16	11.2	36.6
Potatoes	7.01	3.2	11.4
Wheat bran	49.15	54.6	28.6
Linseed meal	105.12	32.2	24.8
Cotton-seed meal	135.65	56.2	29.2
Wheat	37.53	15.8	10.6
Oats	36.42	12.4	8.8
Corn	33.06	11.8	7.4
Barley	39.65	15.4	9.6
Milk	10.20	3.4	3.6
Cheese	90.60	23.0	5.6
Live cattle	53.20	37.2	3.4

The exchange of 1 ton of corn for 1 ton of wheat bran, for instance, will result in a gain of 16 pounds of nitrogen, 43 of phosphoric acid, and 21 of potash. With an exchange of milk or potatoes for the concentrated feeding stuffs the gain is still more striking.

A careful study of the present condition of farming in the United States indicates, however, that as a rule the manure produced on the farm is not sufficient to maintain its fertility and that the need for artificial supplies is real, though the amount required may be considerably reduced by careful management.

In the system of so-called "grain farming" which has obtained over large areas of this country for a long time, and is still practiced in the Eastern, Middle, and Central Western States, the live stock kept is often limited to a number sufficient only to the needs of the farm for labor and food; the grain is sold, and the manure is made up chiefly of the natural wastes, or unsalable material, such as straw, stalks, etc. The grain contains proportionately greater amounts of nitrogen and mineral constituents than these wastes; hence the practice continued for a long time results not only in a deficiency in the soil of organic substances containing nitrogen, but also in an exhaustion of the mineral substances. The original character of the soil and its treatment measure the rate of exhaustion. The less fertile soils of the East and South are rapidly depleted, while the rich prairie and river bottoms maintain their fertility for a longer period.

Special crop farming, as for example the continuous cotton and tobacco growing of the South and the wheat growing of the West, is even more exhaustive, since here the demands upon the soil are not changed—year after year the same crop is grown and the same kind and proportion of constituents are required, while even less returns are made in the way of manure than in the system of farming above described. Moreover, the land is left bare for a large part of the year and loss of fertility from this cause is very large. The crops are less abundant each year, not because the soil is entirely exhausted, but because it is so far exhausted of those constituents essential to the special crop grown that its production is no longer profitable.

Changed conditions of farming, which have an important bearing on this point, may be observed in two directions—(1) in the increased cost of labor and in the lower prices of grain, cotton, and tobacco; and (2) in the increasing demand for market garden products and fruit. For example, in growing wheat, the labor of preparing the soil, of cultivation, and of harvesting is practically the same whether the yield is 10 bushels per acre or 30 bushels. The same is true of a number of other crops; hence in the larger yield the cost of labor per bushel is materially reduced; meager crops of a relatively low value can not be produced profitably with high-priced labor. Soils of a high degree of fertility are required in order to produce large yields of these crops. The return to the soil of only the wastes of the farm results sooner or

later in a decrease in fertility, however good the management may be; hence the need of supplies of plant food from sources outside the farm in order that maximum crops may be produced.

In the case of market garden crops, it has been proven that even very fertile soils contain too little available food to insure a maximum production; this is especially true where rapidity of growth, earliness, and high quality of produce are important factors. The areas now necessarily devoted to these crops are so great that the amount of farm manures available is much too small; besides, the constituents contained in such manures, being slowly available, are less useful than the more active forms contained in commercial fertilizing materials. They are in a sense artificial crops and, as a rule, need artificial supplies of plant food.

Fruit culture, an industry of growing importance, is profitable, particularly on the poorer soils near the Eastern markets, largely in proportion to the supply of the mineral elements in excess of those contained in soils otherwise well adapted to the crops. A sufficiency of food not only enables the trees to resist unfavorable conditions, but improves the quality of the fruit and extends the bearing period of the orchards and vineyards.

It will thus be seen that it is either to make up the deficiencies of farm manures or in specialized intensive farming that commercial fertilizers can be most advantageously used. The latter should supplement and not entirely replace the manurial resources of the farm. They give best results as a rule on soils well stocked with organic matter (humus), a material which can be maintained in soil only by the regular application of the bulky farm manures (including green manures).[1]

FERTILIZER REQUIREMENTS OF DIFFERENT SOILS AND CROPS.

Nitrogen, phosphoric acid, and potash are the constituents most likely to be deficient in soils or most quickly exhausted by the production and removal of crops. These are known as "essential" fertilizing constituents, and the value of a commercial fertilizer is determined almost exclusively by the amount and form of the nitrogen, phosphoric acid, and potash which it contains. It does not follow, however, that all soils or crops will respond equally to applications of materials containing these elements, because the needs of soils and the requirements of crops vary.

Soils differ in respect to their needs for specific elements, owing either to their method of formation or to their management and cropping. A sandy soil is usually deficient in all the essential plant-food constituents—nitrogen, phosphoric acid, and potash—while a clayey soil usually contains the mineral elements in abundance, particularly potash. On the other hand, a soil very rich in vegetable matter is frequently

[1] See Farmers' Buls. 16 and 21 of this Department.

deficient in mineral matter, while a limestone soil is likely to contain considerable proportions of phosphoric acid. These are the indications in a general way, and they explain why it is that different kinds of soil that have not been cropped differ in respect to their needs in reference to the different fertilizing constituents.

Methods of management and cropping also exert an influence; for example, soils of equal natural fertility may not respond equally to uniform methods of fertilization, because in the one case a single crop, requiring for its growth proportionately more of one of the essential elements than of another, is grown year after year, and it may be that the element required is the one that exists in the soil in least quantity. On the other hand, crops may be grown that demand but minimum amounts of the element in question; hence its application to the soil for the one crop may be followed by largely increased returns, while for the other but little if any increase in crop is apparent.

In the matter of management, too, a considerable variation may be observed. One soil may lose a large portion of its essential constituents, because no pains are taken to retain for the use of the crop the constituents annually rendered available through the natural agencies of sun, air, and water; while in another, by means of careful cultivation and the use of absorbents and catch crops, the constituents made available are largely retained.

Crops differ in respect to their power of acquiring food.—The legumes, a class of plants which includes the various clovers, peas, beans, vetches, etc., differ from other plants in being able, under proper conditions, to acquire their nitrogen from the air, and can, therefore, make perfect growth without depending upon soil nitrogen. On the other hand, the various grasses and grains are not only dependent upon soil nitrogen, but they must have an abundance during their most rapid period of growth in order to attain their maximum development. For the latter class of plants favorable results are secured from the proper use of nitrogenous manures, while for the former class the application of nitrogenous manures simply results in supplying an element which could have been secured quite as well by the plant itself, without expense. Illustrations could be multiplied, though perhaps less striking than this, showing that the variations in crops in respect to their power of acquiring food are really very great, and a right knowledge of this fact has a most important bearing upon the economical use of commercial manures.

"The most satisfactory, and, indeed, usually the only method," says Armsby, "by which we can at present determine the needs of a soil is to ask the question of the soil itself by growing a crop upon it with different kinds of fertilizers and noting the result. Such soil tests with fertilizers have in many cases given results of much immediate practical value for the locality in which they were undertaken. As a rule, however, farmers have looked upon such experiments as something too

costly and complicated for them to undertake, and consequently they have perforce been content to use fertilizers in a more or less haphazard manner, and in many cases, no doubt, at a great financial disadvantage."

While such tests are not so difficult or expensive as is often supposed, it is recommended that before the farmer undertakes them for the first time he seek the advice of someone familiar with the details of such work, or, preferably, apply to the experiment station of his State.

FORMS, SOURCES, AND COMPOSITION OF FERTILIZING MATERIALS.

The term "form" as applied to a fertilizing constituent has reference to its combination or association with other constituents, which may be useful, though not necessarily so. The form of the constituent, too, has an important bearing upon its availability, and hence upon its usefulness as plant food. Many materials containing the essential elements are practically worthless as sources of plant food because the form is not right; the plants are unable to extract them from their combinations; they are "unavailable." In many of these materials the forms are changed by proper treatment, in which case they become valuable not because the element itself is changed, but because it then exists in such form as readily to feed the plant.

NITROGEN.

Nitrogen is the most expensive of the three essential fertilizing elements. It exists in three distinct forms, viz, as organic matter, as ammonia, and as nitrate.

Organic nitrogen exists in combination with other elements either as vegetable or animal matter. In fact all plants and animals contain nitrogen in this form, and the relative value of the various substances as sources of nitrogen depends upon their content of it and upon the character of the substance and its treatment. All materials containing organic nitrogen are valuable in proportion to their rapidity of decay or change, because decay and change of form must take place before the nitrogen can serve as food. In some cases the decay is longer delayed than in others. The material may be hard and dense, or it may have been treated for the express purpose of preventing decay, or it may be associated with other substances that resist the agents which effect decay. Thus organic nitrogen differs in availability not only according to the kind of material which supplies it, but upon the treatment it receives.

The most abundant supplies of nitrogen occur in organic forms. The most valuable sources of organic nitrogen, from the standpoints of uniformity in composition, richness in the constituent, and availability, are dried blood, dried meat, or azotine, and concentrated tankage, which are produced in large quantities in slaughterhouses and rendering

establishments; dried fish, refuse from fish-oil and canning establishments; and cotton-seed meal, the residue of the cotton seed after the oil has been extracted. These vary somewhat in composition, but within comparatively narrow limits (see table, p. 25). They are all rich in nitrogen, and decay rapidly when the conditions are favorable, and are very useful in cases where rapid and continuous feeding of the plant with nitrogen is desirable.

These products, while valued principally as sources of nitrogen, also furnish more or less phosphoric acid, the dried blood and meat showing the least and the fish the greatest amount. Other nitrogenous materials which are less desirable are leather meal, horn and hoof meal, wool waste, felt waste, and similar products. These contain, as a rule, a high content of nitrogen, but they are so very slow to decay that it is doubtful whether their use in their original form is advisable when forms of known value are available at reasonable prices. Where the object is gradually to increase the fertility of the soil rather than to secure immediate returns, they may become useful. Farmers frequently have access to local supplies at a slight cost, the chief expense being the labor of carting and distributing, in which case they are worth considering.

Nitrogen as ammonia exists in commercial manure products in the form of sulphate of ammonia, chlorid of ammonia, etc., and is more readily available than organic forms. It is one of the first products that results from the decay of organic substances.

Nitrogen in the form of ammonia is obtained almost entirely from sulphate of ammonia, which is one of the most concentrated materials from which nitrogen is obtained for fertilizing purposes, the commercial product containing on the average 20 per cent of nitrogen. As already indicated, ammonia is one of the first products in the decay of organic substances, and this, together with the fact of its concentration, makes the sulphate an extremely valuable form of nitrogen. While it is extremely soluble in water, it is not readily removed from the soil by leaching, except in the absence of growing plants, since it is readily absorbed by organic and other compounds of the soil.

Nitrogen as nitrate exists in commercial products as nitrate of soda, nitrate of potash, etc. These, like the ammonia compounds, are extremely soluble, and the nitrogen contained in them is readily available as food for plants. The nitrogen in this form is directly and immediately available, no further changes being necessary.

The chief source of nitrogen as nitrate is nitrate of soda. This salt is rich in nitrogen, showing on the average 16 per cent, and is quite uniform in composition. It is completely soluble in water, diffuses readily throughout the soil, and differs from the ammonia compounds in forming no insoluble compounds with soil constituents. It is, therefore, liable to be washed out of the soil if applied in too large quantities or when there is an absence of vegetation. Plants that derive

their nitrogen from the soil secure it chiefly in the form of a nitrate; hence nitrate of soda is one of the most directly useful of the nitrogenous materials.

As already explained, nitrogen in organic forms is changed into ammonia by the decay or rotting of the substance. Ammonia, while it may nourish plants directly, is usually changed into a nitrate, in which form it is taken up by the plant. An application of nitrogen as nitrates may be completely used by the plant in a very short time; as ammonia or organic matter it may be partially or wholly used in the course of a season, depending upon whether the conditions are favorable for causing the changes that must take place.

PHOSPHORIC ACID.

Phosphoric acid is derived from materials called phosphates, in which it may exist in combination with lime, iron, or alumina as phosphates of lime, iron, or alumina. Phosphate of lime, however, is the form most largely used as a source of phosphoric acid. Phosphoric acid occurs in fertilizers in three forms: That soluble in water and readily taken up by plants; that insoluble in water, but still readily used by plants, also known as "reverted;" and that soluble only in strong acids and consequently very slowly used by the plant. The soluble and "reverted" together constitute the "available" phosphoric acid. The phosphoric acid in natural or untreated phosphates is insoluble in water and not readily available to plants; that is, the rate of availability depends largely upon the rapidity with which the substance rots or decays, and the rate of decay again depends upon the character of the substance with which the phosphate is associated. If it is combined with organic substance, as in animal bone, the rate of decay is more rapid than if with purely mineral substances. The insoluble phosphates are converted into soluble forms by treatment with strong acids, as explained later. Such products are known as acid phosphates or superphosphates.

Bone, in its various forms, is the only one of the insoluble phosphates that is now used directly upon the soil, or without other change than is accomplished by mechanical action or grinding. The terms used to indicate the character of the bone have reference rather to their mechanical form than to the relative availability of the phosphoric acid contained in them. The terms "raw bone," "fine bone," "boiled and steamed bone," etc., are used to indicate methods of preparation, and inasmuch as bone is a material which is useful largely in proportion to its rate of decay, its fineness has an important bearing upon availability, since the finer the bone the more surface is exposed for the action of those forces which cause decay or solution, and the quicker will the constituents become available. In the process of boiling or steaming, not only is bone made finer, but its physical character in other respects is also changed, the particles, whether fine or coarse,

being made soft and crumbly rather than dense or hard; hence it is more likely to act quickly than if the same degree of fineness be obtained by simple grinding. The phosphoric acid in fine steamed bone may all become available in one or two years, while the coarser fatty raw bone sometimes resists final decay for three or four years, or even longer. Bone, however, contains considerable nitrogen, a fact which should be remembered in its use, particularly if used in comparison with other phosphatic materials which do not contain this element.

Pure raw bone contains on an average 22 per cent of phosphoric acid and 4 per cent of nitrogen. By steaming or boiling, a portion of the organic substance containing nitrogen is extracted, which has the effect of proportionately increasing the phosphoric acid in the product; hence a steamed bone may contain as high as 28 per cent of phosphoric acid and as low as 1 per cent of nitrogen. Steamed bone is usually, therefore, much richer in phosphoric acid than raw bone.

Tankage is a bone product which, as a rule, contains more nitrogen than bone proper. It is also more variable in its composition, depending upon the proportions of bone and meat used in its preparation. It is not so largely used as a direct fertilizer as bone.

Other phosphates derived from bone, as boneblack, bone ash, etc., are but little used directly as sources of phosphoric acid; for while they are derived from organic sources, the treatment which they have received, besides depriving them of their nitrogen, causes them to be a much less valuable source of phosphoric acid than the various forms of bone already discussed. In both cases the organic substances which show the greater tendency to decay have been removed—in the case of boneblack by heating the bone in air-tight vessels, and in bone ash by burning in the open air.

The mineral phosphates differ from what may be termed "organic phosphates" in that they contain no organic or animal matter, and that they are more compact and dense in their nature. The chief sources of these phosphates are the river and land phosphates of South Carolina, the "soft," "pebble," and "rock" or "bowlder" phosphates of Florida, the "apatites" of Canada, the phosphate mines of Tennessee, and phosphatic slag,[1] a waste product from the manufacture of steel from phosphatic iron ores. With the exception of the latter, which is not an abundant product in this country, these phosphates are not yet used to any considerable extent, even when very finely ground[2] without having been treated with acid. They are, however, the chief raw materials from which superphosphates are made.

Superphosphates, or soluble phosphates, are derived from the insoluble materials already described by first grinding to a powder and

[1] Also known as Thomas Phosphate Powder, Thomas slag, and Odorless Phosphate.

[2] Finely ground mineral phosphate known as "floats" has been used to a limited extent in some localities.

then mixing with sulphuric acid, which changes the insoluble phosphoric acid to the soluble form. The soluble phosphoric acid thus obtained is a definite chemical compound, and is identical in composition whatever may have been the material from which it was derived. The term superphosphate is, therefore, applied to any material containing soluble phosphoric acid as its chief constituent. In superphosphates there is nearly always present, however, in addition to the soluble, the reverted form, which is probably quite as useful as the soluble form. The superphosphates made from boneblack and bone ash differ from the mineral superphosphates mainly in showing a higher content of "available" phosphoric acid, an average of 16 per cent, which is practically all soluble. Mineral superphosphates contain on the average 14 per cent of available, which may include from 1 to 3 per cent of reverted, besides more or less of the insoluble. Superphosphates made from animal bone differ from those made from the other materials mentioned in containing nitrogen in addition to phosphoric acid. They are, however, sometimes called "ammoniated superphosphates" or "dissolved ammoniated bone."

In the use of phosphoric acid, therefore, it must be remembered that the source has an important bearing in determining whether it is used as a phosphate or as a superphosphate. As regards the untreated phosphates, it must be remembered that those derived from organic substances, such as bone, are the more valuable because of their greater tendency to decay and greater ease of solution, and that this tendency to decay is promoted by such means as will increase the fineness of division. In the case of superphosphates, those which contain the greatest proportion of soluble phosphoric acid are relatively the most valuable, because the soluble phosphoric acid readily distributes itself in the soil and goes to the roots of plants, while the reverted remains where it is placed and the roots of the plants must come to it. In the next place, it should be remembered that phosphoric acid is not washed from the soil, though in a soluble form, since it is finally "fixed" by coming in contact with lime, iron, and other mineral substances usually present in good soils.

POTASH.

Potash may exist in a number of forms, though chiefly as chlorids, or muriates, in which case the potash is combined with chlorin; and as sulphates in which the potash is combined with sulphuric acid. With potash, however, the form does not exert so great an influence upon availability as is the case with nitrogen and phosphoric acid. All forms are freely soluble in water, and are believed to be nearly if not quite equally available as food. The form of the potash has, however, an important influence upon the quality of certain crops, due rather to the constituents with which the potash is associated than to the potash itself. For example, it has been demonstrated that the quality of tobacco, potatoes, and certain other crops is unfavorably influenced by the use

of muriate of potash, while the same crops show a superior quality if materials free from chlorids have been used as the source of potash applied.

The chief sources of potash salts at the present time are the Stassfurt mines of Germany, and the products of these mines, which are now readily obtainable in this country, are kainit, sylvinit, muriate of potash, high-grade sulphate of potash, and double sulphate of potash and magnesia, or double manure salts. The kainit and sylvinit are crude products of the mines, and contain, in addition to potash, a number of other salts, chiefly ordinary salt (sodium chlorid) and magnesium sulphate. The potash in kainit, though in the form of a sulphate, produces an effect quite similar to that derived from the use of muriate, because of the large quantities of chlorids mixed with it. It contains on the average about 12½ per cent of actual potash. Sylvinit differs from kainit in containing a slightly higher per cent of potash, which exists both in the form of a sulphate and of a chlorid, and a lower content of the magnesia and other salts. The other potash products mentioned are manufactured from the crude forms, and are much more concentrated. The muriate and sulphate contain on the average about 50 per cent of actual potash. The chief impurity in the case of the muriate is common salt. The double sulphate of potash and magnesia contains about 26 per cent of actual potash, though much lower grades of this material are found.

Materials that do not show a wide variation in composition, and in which the constituents are practically uniform in their action, may be regarded as standard in the sense that they can be depended upon to furnish practically the same amount and form of the constituents wherever secured. For example, a ton of nitrate of soda or boneblack superphosphate (dissolved boneblack) will on the average furnish 320 pounds of nitrogen or of phosphoric acid, the nitrogen all in the form of a nitrate and the phosphoric acid practically all soluble; whereas a ton of tankage, for instance, will vary widely both in the content and in the availability of its nitrogen and phosphoric acid, depending upon the method by which it has been derived. Hence, nitrate of soda, sulphate of ammonia, dried blood, and superphosphates and potash salts are standard products, because they can be depended upon both in respect to the content and form of their constituents.

AGRICULTURAL V. COMMERCIAL VALUE OF FERTILIZERS.

The agricultural value of any of the fertilizing constituents is measured by the value of the increase of the crop produced by its use, and is, of course, a variable factor, depending upon (1) the availability of the constituent, and (2) the value of the crop produced. For example, in the first case, the agricultural value of a pound of soluble phosphoric acid is likely to be greater than that of a pound of insoluble when applied under the same conditions as to soil and crop, because in the one case

the element is in its most available form, while in the other it is least available. In the second place, the soluble phosphoric acid may exert its full effect and cause a greatly increased yield on a certain crop, and still not cause an increase in value sufficient to pay the cost of the application, while for another crop the application may result in a very great increase in value. The character or form of the materials used must, therefore, be carefully considered in the use of manures. Slow-acting materials can not be expected to give profitable returns, particularly upon quick-growing crops, nor expensive materials such profitable returns when used for crops of relatively low value as for crops of relatively high value.

This agricultural value is, however, separate and distinct from what is termed "commercial value," or cost in market. This value is determined by market and trade conditions, as cost of production of the crude materials, methods of manipulation required, etc. Since there is no strict relation between agricultural and commercial or market value, it frequently happens that an element in its most available form, and under ordinary conditions of high agricultural value, costs less in market than the same element in less available forms and of a lower agricultural value. The cost of production in the one case is lower than in the other, though the returns in the field are far superior.

The commercial value has reference to the material as an article of commerce, hence commercial ratings of various fertilizers have reference to their relative cost and are used largely as a means by which the different materials may be compared.

VARIATIONS IN THE COMPOSITION OF MANUFACTURED FERTILIZERS.

All manufactured products or brands of fertilizers are made up of a mixture of the various kinds and forms of the fertilizing materials just described, and the differences that exist in the brands of different manufacturers are due both to differences in the character and to variations in the proportions of the materials used to form the different brands; that is, while all manufacturers must go to the sources of supply indicated, they may select either good or poor products and may vary the proportions of the different materials used.

The difference between a good brand of fertilizer and a poor one lies not so much in differences that may exist in the total amount of plant food contained in it as in the quality of the materials of which it is made. For instance, in one brand the nitrogen may have been derived entirely from insoluble organic materials and the phosphoric acid from untreated phosphates rather than superphosphates; while in another the nitrogen may have been derived from the three sources of nitrogen, viz, nitrates, ammonia salts, and organic matter, and the phosphoric acid entirely from superphosphates. In the first brand the total food contained may be quite as great as in the other, yet the immediate results obtained from its use would be less satisfactory than that

obtained from the one containing the more active forms of fertilizing constituents.

The differences that exist between good and poor fertilizers are quite clearly shown by the chemical analyses made by the various experiment stations, provided the analysis is carried far enough to show both the amount and form of the nitrogen, phosphoric acid, and potash. For instance, an analysis which shows that a considerable proportion of the nitrogen exists as nitrates or as ammonia is positive evidence that good nitrogenous materials have been used; if it shows that the phosphoric acid is largely in a soluble form, the consumer knows that superphosphates have been used. On the other hand, if all the nitrogen is shown to be in the form of organic matter, and that a large proportion of the phosphoric acid is insoluble, it is evident that materials containing less active forms of plant food have been used. In the next place, it is the quality and amount of plant food that is contained in a fertilizer which determines its value rather than the relative proportion of the various constituents, though under certain well-known conditions the latter is of very considerable importance. Special crop brands are particularly useful only when an abundance of all the plant-food constituents are present in the soil.

THE PURCHASE OF FERTILIZERS.

As a rule, farmers are inclined to purchase fertilizers on the ton basis, without sufficient regard to the content or form of the constituents contained in them. The direct value of a fertilizer is determined by the percentage of nitrogen, phosphoric acid, or potash which it contains. Hence, the buying of a fertilizer is virtually the buying of one or more of these constituents. The more concentrated the material or the richer it is in plant food the less will be the expense of handling the constituent desired.

The following are illustrations of the methods by which brands may be made up, the differences that may exist in the content of actual fertilizing constituents, and the causes of variation in ton prices:

Formula No. 1.

Nitrate of soda	500 lbs.,	furnishing nitrogen	80 lbs., or 4 p. ct.
Boneblack superphosphate	1,100 lbs.,	furnishing phosphoric acid	180 lbs., or 9 p. ct.
Muriate of potash	400 lbs.,	furnishing potash	200 lbs., or 10 p. ct.
Total	2,000 lbs.,	furnishing total plant food	460 lbs.

Formula No. 2.

Nitrate of soda	250 lbs.,	furnishing nitrogen	40 lbs., or 2 p. ct.
Boneblack superphosphate	1,000 lbs.,	furnishing phosphoric acid	160 lbs., or 8 p. ct.
Muriate of potash	80 lbs.,	furnishing potash	40 lbs., or 2 p. ct.
Make-weight	670 lbs.		
Total	2,000 lbs.,	furnishing total plant food	240 lbs.

Formula No. 1 shows a high-grade product, both in respect to quality of plant food and concentration, while No. 2 is high-grade only in respect to quality. In order that the plant food may be contained in 1 ton it is necessary to add what is called "make-weight," or a diluent, usually consisting of substances that contain no direct fertilizing value.

"High-grade mixtures can not be made from low-grade materials. Low-grade mixtures can not be made from high-grade materials without adding 'make-weight.' The advantages of high-grade products are concentration and high quality of plant food."[1]

It will be observed that formula No. 1 contains nearly twice as much plant food as No. 2; or, in other words, it will require about 2 tons of a fertilizer made according to formula No. 2 to secure the same total amount of plant food as is contained in 1 ton of No. 1. Now, the material in No. 2 other than the actual plant food is of no direct fertilizing value, but the actual cost of the constituents is considerably increased, because the expenses of handling, bagging, shipping, and selling are just double what they would be for No. 1.

It has been shown by continued studies at the New Jersey Experiment Station that the charges of the manufacturers and dealers for mixing, bagging, shipping, and other expenses are, on the average, $8.50 per ton; and also that the average manufactured fertilizer contains about 300 pounds of actual fertilizing constituents per ton. A careful study of the fertilizer trade indicates that these conditions are also practically true for other States in which large quantities of commercial fertilizers are used.

Formula No. 1 would contain 460 pounds of actual available fertilizing constituents per ton—160 pounds, or over 50 per cent, more than is contained in the average manufactured brand. That is, a farmer purchasing a brand similar to formula No. 1 would secure in 2 tons as much plant food as would be contained in 3 tons of the average manufactured brand. Assuming that the charges per pound of plant food at the factory, and that the expense charges are the same in each case, and also that the quality of plant food in the one is as good as in the other, the consumer would save $8.50 by purchasing 2 tons of the former instead of 3 tons of the latter. In a few States the consumption of **fertilizers ranges from 150,000 to over 300,000 tons annually, while in many it is from 25,000 to 50,000 tons.**

Thus is shown the very great saving that may be effected in the matter of the purchase of fertilizers from the standpoint of concentration alone, or, in other words, the importance of a definite knowledge of what constitutes value in a fertilizer. This saving may be accomplished, too, without any detriment to the manufacturer, since the difference to him between making high-grade or low-grade goods, in reference to concentration, is largely a matter of unskilled labor. The manufacturers are in the business to cater to the demands of the trade;

[1] First Principles of Agriculture, E. B. Voorhees, p. 109.

if consumers are intelligent, high-grade rather than low-grade goods will be provided by the manufacturers. Furthermore, as already indicated, high-grade in the matter of concentration means high-grade in quality, for high-grade mixtures can not be made from low-grade products.

In many cases, too, it is desirable to purchase the unmixed fertilizing materials, either for use singly or to be mixed at home. Here, too, a great saving may be effected—(1) in the cost per pound of the constituents; (2) in freight rates, and (3) in having the mixing performed by the ordinary labor of the farm, at times when it does not interfere with regular outdoor work. The advantages to be derived from this method are, however, fully realized only when it is possible to purchase in large quantities for cash.

As an illustration of the saving that may be effected, it is but necessary to cite the experience of a farmers' organization in New Jersey, which now purchases annually some 500 or 600 tons of unmixed goods. The cost per pound of the ingredients is to them over 40 per cent less than the average cost to those who buy the average mixture in small quantities "on time" from their local dealers.

It has been shown, too, by the studies of many of the experiment stations of both the East and South that the materials can be evenly mixed on the farm; besides, samples carefully taken show as good a mechanical condition as those made by the leading manufacturers.

This method of purchasing also possesses the further advantage of enabling the farmer to apply just the kind and form of ingredient that he has found by experience or experiment to be best adapted to his soil and crop. Besides, he knows positively, particularly in case of the element nitrogen, whether it is in the form of nitrate, ammonia, or organic matter, and whether the organic nitrogen is contained in substances that are likely to decay quickly, as blood, cotton-seed meal, etc., or in such insoluble and slow-acting substances as ground leather, horn, etc. In mixtures the kind of organic nitrogenous substances used can not be definitely shown by a chemical analysis.

CONDITIONS UNDER WHICH FERTILIZERS MAY BE PROFITABLY USED.

With a more or less complete knowledge of the need of artificial supplies of fertilizer, the character, composition, and usefulness of the various materials, and the best method of purchase, the practical question arises, Will it pay to use them? Many of our most successful farmers are by their practice answering this question in the affirmative. It is, however, not entirely a question of plant food with them, and one phase of it may be illustrated by the following typical case: Mr. A applies fertilizer, his crop is doubled or tripled, and a reasonable profit is secured. Mr. B applies the same amount and kind under similar natural conditions of soil and receives no benefit. The difference in results is due not to the fertilizer, but to the farmer himself. In

one case the natural agencies—sun, air, and water—were assisted and enabled to do their maximum work, because care was taken to make the conditions other than the supply of plant food as perfect as possible, while in the other they were prevented from exercising their full influence because physical conditions of soil were imperfect, due to careless plowing, seeding, cultivation, and cropping.

In other words, the profit from the use of fertilizers is measured to a large degree by the perfection of soil conditions which are entirely within the power of the farmer to control. The production possible from a definite amount of plant food can be secured only when the conditions are such as to permit its proper solution, distribution, and retention by the soil.

The fact that fertilizers may now be easily secured and are easily applied has encouraged careless use rather than a thoughtful expenditure of perhaps an equivalent amount of money or energy in the proper preparation of the soil for them. Of course it does not follow that no returns are secured from plant food applied under unfavorable conditions, but it needs to be emphasized that full returns can not be obtained under such circumstances either with or without fertilizers. Good plant food is wasted and the profit possible to be derived is largely reduced. Moreover, farming in its strict sense is the conversion of three essential elements into salable products, and therefore the use of plant food must be governed largely by its cost, and the kind of crop upon which it is applied.

The very high prices paid by many for fertilizers—though admittedly due to their lack of knowledge concerning what constitutes value in a fertilizer and to irrational methods of buying—renders it impossible to secure a reasonable profit by their unsystematic use upon such staple products as wheat, corn, oats, cotton, and tobacco, because these crops absorb relatively large amounts of the manurial constituents, and are at the present time products of relatively low value.

The bushel or pound of crop contains a high content relatively of the fertilizing constituents while the selling price is low, thus leaving but a narrow margin between the cost of the constituent and the price received for it in the product.

The growth of such crops as potatoes, tomatoes, sweet potatoes, forage crops for the dairy, and vegetable crops for the market or cannery by the use of high-priced plant food is more often attended with profit, because they are usually crops of high market value and are proportionately less exhaustive. This does not mean that the former crops shall be abandoned, but rather that our systems of practice shall be changed so as to include in the rotation some high-priced crop to which shall be applied such an abundance of plant food as to insure a yield, limited only by the season and climate, which will, under average conditions of soil and season, yield a profit, besides leaving a residue of plant food for the cereals, grasses, or catch crops that follow. These

being capable of extracting their mineral food from relatively insoluble sources will yield a large increase of crop without a direct outlay for fertilizers. Farming will thus be more successful, because profitable crops are secured, while at the same time fertility is increased.

THE KIND OF FERTILIZER TO USE.

The kind of fertilizer to use should be considered (1) in reference to whether it shall be nitrogenous, phosphatic, or potassic in its character, and not to whose brand shall be used; and (2) as to the form in which the fertilizing constituents exist, whether quickly or slowly available. A proper understanding of these points requires that we shall consider briefly the various classes of farm crops and their power of acquiring food.

The cereals, Indian corn excepted (see p. 23), and grasses are quite similar in their habits of growth, and may be regarded as a class distinguished by extensive root systems and long periods of growth, which enable them to extract the mineral food necessary from relatively insoluble sources, and because of their very rapid development of leaf and stem during a short season just before maturity are unable to make normal growth during this period without an abundance of nitrogen in immediately available forms. This period usually precedes the time of rapid nitrification; hence on soils of good natural fertility the application of nitrogen at the right time and in the form of a nitrate results in a largely increased crop. The fact here stated has led certain eminent scientists to regard nitrogen as a dominant or ruling element for this class of plants, and it is true if the limitations are properly understood.

The leguminous crops—clover, peas, beans, vetches, etc.—should also be regarded as a distinct class. They possess powers of acquiring food which, as far as we know now, are not common to any other class of plants. They do not depend altogether upon soil sources for their nitrogen, but draw this element partly from the air, and they make almost ravenous use of the mineral constituents, particularly potash and lime. A knowledge of these facts is not only useful in indicating what kind of manures to use, viz, an abundance of the mineral constituents only, but suggests that the growth of these crops must result in the enrichment of soils in the expensive element, nitrogen, so essential for crops whose exclusive source of supply is the soil.[1]

Root and tuber crops may also be regarded as a class which, because of their habits of growth, are unable to make ready use of the insoluble mineral constituents of the soil, and hence for full development require an abundance of all the fertilizing constituents in readily available forms. Of the three classes of fertilizing constituents, the nitrogen is especially useful for the slow-growing beets and mangels; soluble phosphates are required in abundance for the turnip; and potatoes,

[1] Farmers' Bul. 16 of this Department.

white and sweet, respond favorably to liberal dressings of potash. That is, while the fertilizers should contain all three elements, certain of the crops, because of their peculiarities of growth, require certain of them in greater relative amounts and in immediately available forms.

The object of the growth, too, whether for the immature produce or for the fully developed plant, is a matter worthy of careful consideration. In other words, Shall the fertilizing be of such a character as to stimulate and force an unnatural and artificial growth, or such as assists in the natural development of the plant? That the specific function of nitrogenous manures is to encourage and even force leaf development is a fact not disputed by the highest authority; hence their use in stimulating unusual growth is of the greatest importance in growing market-garden crops, in order that the tenderness and succulence, which is the measure of quality in most of those products, may be secured.

Fruit trees are slow-growing plants and therefore do not need quick-acting fertilizers as a rule. They appropriate plant food very slowly, and highly soluble manures, such as nitrate of soda, are liable to be washed out of the soil without being utilized. For this reason the use of nitrate of soda is not advised except where the growth of nursery stock is to be forced or where bearing trees exhibit a lack of luxuriance in foliage. The old and still common practice of fertilizing fruit trees every few years with slowly decomposing manures, such as barnyard manure, leather waste, horn refuse, wool waste, leaf mold, tobacco stems, etc., is thus seen to have more or less of a scientific basis. Frequently, however, it is desirable to stimulate the growth and fruitfulness of the trees, and for this purpose more active fertilizing materials than the above are needed. In selecting and mixing the latter the fact that fruits are "potash feeders" should be taken into consideration.

Probably there is no better fertilizer for fruit trees than a mixture of muriate of potash and ground bone (1 part of the former to 1½ parts of the latter). A good practice is to apply this mixture to clover or some other leguminous crop which is turned under as a green manure, and in addition, where tobacco stems can be obtained cheaply, to apply these about the trees. Wood ashes or cotton-hull ashes may be substituted for muriate of potash if these products can be obtained at reasonable prices.

The fertilizer requirements of small fruits are similar to those of orchard fruits, but being as a rule more rapid growers they can utilize to advantage heavier applications of soluble fertilizing materials and do not derive the same benefit as orchard fruits from slowly decomposing manures.

In deciding upon the kind of manure to use the character of the soil must, of course, be taken into account. Crops grown on soils poor in decaying vegetable matter (humus) are as a rule benefited by applications of nitrogenous manures, while those grown upon soils well

supplied with this substance are more benefited by phosphates and potash. Upon heavy soils phosphates are likely to be more beneficial than nitrogen, while the reverse is the case on light dry soil. All sandy soils are as a rule deficient in potash, while clayey soils contain this element in larger quantities (see p. 7).

In this discussion the barest outlines have been drawn. There are many exceptions to the general rules. The farmer, with the general principles well in mind, must use his intelligence in applying them to his conditions.

FERTILIZERS SHOULD BE APPLIED SYSTEMATICALLY.

The suggestions already given lead to another of great importance, viz, that the use of fertilizers should be systematic. In order that this may be accomplished, a definite system of cropping should be adopted and a definite scheme of manuring worked out that shall meet the conditions of crop, season, and climate, and enable the farmer to utilize to the best advantage home and local supplies of manure. While it is impossible to give more than the merest outline of such methods, the following suggestions are offered:

In the first place, in nearly every State or even locality some one system of cropping is better adapted to the conditions than another. It may be the extensive system, which includes large areas, and the crops, grain, cotton, tobacco, or sugar cane; or the "intensive system," with smaller areas and crops of quicker growth and higher value. For the former a method of manuring should be adopted which is not too expensive, but which provides for increased crops and gradual gain in fertility. It would be impracticable in extensive farming, for example, to attempt to increase the yield of a wheat crop from 12 to 30 bushels per acre by the addition of fertilizers only, for, as already pointed out, plant food is but one of the conditions of fertility, and if it were practicable from the standpoint of yield, it would be folly from the standpoint of profit.

A study of the following common four-year rotations—Indian corn, potatoes, wheat, and hay—will illustrate what is meant by rational and systematic methods of manuring. On soils of medium fertility spread the farm manure during the fall and winter, and after the land is plowed apply broadcast and harrow in, or harrow first and then drill in, 400 pounds per acre of a mixture made of 100 pounds each of cottonseed meal, ground bone, acid phosphate, and muriate of potash, or their equivalent in kind and form of other fertilizing constituents.

This mixture would have approximately the following composition: Nitrogen 2.5 per cent, phosphoric acid 10 per cent, and potash 12.5 per cent. If the land has not been previously manured, or if it is of a light sandy character, the proportion of nitrogenous matter should be increased and the application be heavier, say, from 600 to 800 pounds.

Corn makes its most rapid growth and development during the hot season, which is very favorable for rapid decay and consequent nitrification of organic substances in the soil. The nitrogenous manures, therefore, may be less in amount than for crops which develop rapidly earlier in the season, and for the same reason may consist of organic forms. The mineral constituents, particularly the phosphates, which the crop acquires less readily, because of its comparatively short season of growth, are applied in such forms and in such amounts as to provide for a largely increased crop, even though the seasonal conditions are not perfect.

For the potatoes, as a minimum application 650 pounds per acre of the following mixture may be used:

Fertilizer for potatoes.

	Pounds.
Nitrate of soda	50
Cotton-seed meal	150
Ground bone	100
Acid phosphate	200
Muriate or sulphate of potash	150

This mixture contains—nitrogen 3 per cent, phosphoric acid 8 per cent, and potash 12 per cent. In this application we are guided by certain other well-defined principles, chief of which are: This is usually the money crop of the rotation; we can therefore afford a more expensive manuring. Since it grows and matures in a comparatively short time, we need to furnish a reasonable excess of plant food in order that the crop may be abundantly supplied even though unfavorable conditions occur. It is a crop which is particularly benefited by potash, and we must therefore provide that element in largest proportion; and as it is not an exhaustive crop, we may expect considerable increase in soil fertility due to the unused residue.

After the potatoes are removed the land, on account of the frequent cultivation of the potato crop, is in fine mechanical condition essential for the rapid germination and early growth of wheat. It is also well supplied with plant food because of the manure applied to the previous crops in excess of their needs.

For the wheat, therefore, such home supplies of manure as are available may be applied after plowing and well worked into the surface soil with the addition at time of seeding of 200 pounds per acre of dissolved bone, or a mixture of 100 pounds each of ground bone and acid phosphate. In spring, if the crop does not show a vigorous condition, sow broadcast 100 pounds per acre of nitrate of soda.

By this method the manuring is accomplished at a minimum expense, and the phosphates which are so essential for the proper development of the grain are provided, partly in an immediately available form, partly in a form that will gradually decay and feed the crop at later stages of growth. The nitrogen is applied when the plant has greatest

need for it and in a form immediately available, while for potash the plant depends entirely upon the accumulated soil supplies. The hay crop which follows, if it consists of clover, will be able to make normal growth with added supplies of phosphoric acid and potash only, which may consist of a mixture of equal parts of acid phosphate and muriate of potash at the minimum rate of 200 pounds per acre.

This method of fertilizing should not be changed from year to year, but followed in the succeeding rotation courses, and it will enable the farmer to secure an increased yield and improvement in soil at a minimum expense.

The principles involved may also be applied in other lines of farming, modified by character of soil, climate, and kind of crop. In market gardening the amounts applied should be proportionately increased, and a larger proportion of the more active forms used, because in this case quick-growing crops which belong to the high-value class are produced. For fruit trees, which feed slowly and continuously, the mineral elements, as already explained, should be applied in greater amounts, and may be derived from the cheaper and more slowly available forms.

SUMMARY.

(1) Commercial fertilizers are mainly valuable because they furnish the elements—nitrogen, phosphoric acid, and potash—which serve as food, not as stimulants.

(2) The kind of farming in the past and the demands for special products in the present make their use necessary in profitable farming.

(3) In order to use them profitably the farmer should know—

(*a*) That nitrogen, phosphoric acid, and potash are the essential manurial constituents;

(*b*) That the agricultural value of these constituents depends largely upon their chemical form;

(*c*) That these forms are contained in specific products of a well-defined character and composition, and may be purchased as such from dealers and manufacturers and may be mixed successfully on the farm.

(4) The agricultural value of a fertilizer bears no strict relation to the commercial value; the one is determined by soil, crop, and climatic conditions, the other by market conditions.

(5) The variations in the composition and value of manufactured fertilizers which contain the three essential constituents are due to variations in the character and in the proportion of the materials used.

(6) The ton basis alone is not a safe guide in the purchase of these commercial fertilizers. Low ton prices mean either low content of good forms of plant food or the use of poorer forms. Fertilizers, high-grade both in quality and quantity of plant food, can not be purchased at a low price per ton.

(7) The best fertilizers can not exert their full effect on soils that are too dry or too wet, too compact or too porous. They can furnish but one of the conditions of fertility.

(8) The kind and amount to use should be determined by the value of the crop grown and its power of acquiring food.

(9) A definite system or plan should be adopted in their use; "hit or miss" methods are seldom satisfactory, and frequently very expensive.

Composition of the principal commercial fertilizing materials.

	Nitrogen.	Available phosphoric acid.	Insoluble phosphoric acid.	Total phosphoric acid.	Potash.	Chlorin.
1. Supplying nitrogen:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nitrate of soda	15.5 to 16					
Sulphate of ammonia	19 to 20.5					
Dried blood (high grade)	12 to 14					
Dried blood (low grade)	10 to 11			3 to 5		
Concentrated tankage	11 to 12.5			1 to 2		
Tankage (bone)	5 to 6			11 to 14		
Dried fish scrap	7 to 9			6 to 8		
Cotton-seed meal	6.5 to 7.5			1.5 to 2	2 to 3	
Castor pomace	5 to 6			1 to 1.5	1 to 1.5	
2. Supplying phosphoric acid:						
South Carolina rock phosphate			26 to 28	26 to 28		
South Carolina rock superphosphate (dissolved South Carolina rock phosphate)		12 to 15	1 to 3	13 to 16		
Florida land rock phosphate			33 to 35	33 to 35		
Florida pebble phosphate			26 to 32	26 to 32		
Florida superphosphate (dissolved Florida phosphate)		14 to 16	1 to 4	16 to 20		
Boneblack			32 to 36	32 to 36		
Boneblack superphosphate (dissolved boneblack)		15 to 17	1 to 2	17 to 18		
Ground bone	2.5 to 4.5	5 to 8	15 to 17	20 to 25		
Steamed bone	1.5 to 2.5	6 to 9	16 to 20	22 to 29		
Dissolved bone	2 to 3	13 to 15	2 to 3	15 to 17		
Thomas slag				[1] 11.4 to 23		
3. Supplying potash:						
Muriate of potash					50	45 to 48
Sulphate of potash (high grade)					48 to 52	.5 to 1.5
Sulphate of potash and magnesia					26 to 30	1.5 to 2.5
Kainit					12 to 12.5	30 to 32
Sylvinit					16 to 20	42 to 46
Cotton-hull ashes [2]				7 to 9	20 to 30	
Wood ashes (unleached) [2]				1 to 2	2 to 8	
Wood ashes (leached) [2]				1 to 1.5	1 to 2	
Tobacco stems	2 to 3			3 to 5	5 to 8	

[1] In good Thomas slag at least 80 per cent of the phosphoric acid should be soluble in ammonium citrate, i. e., available.

[2] Cotton-hull ashes contains about 10 per cent of lime, unleached wood ashes 30 to 35 per cent, and leached wood ashes 35 to 40 per cent.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

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No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24.
No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
No. 21. Barnyard Manure. Pp. 32.
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